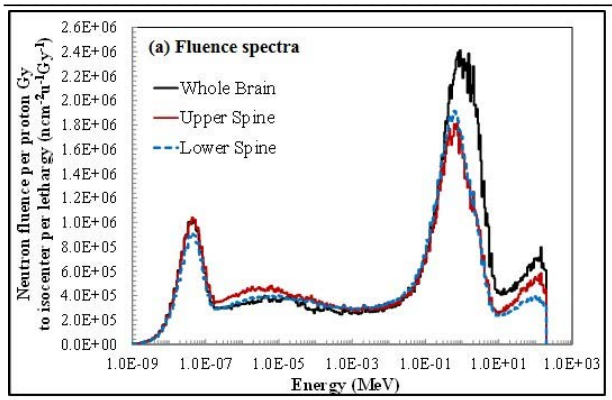

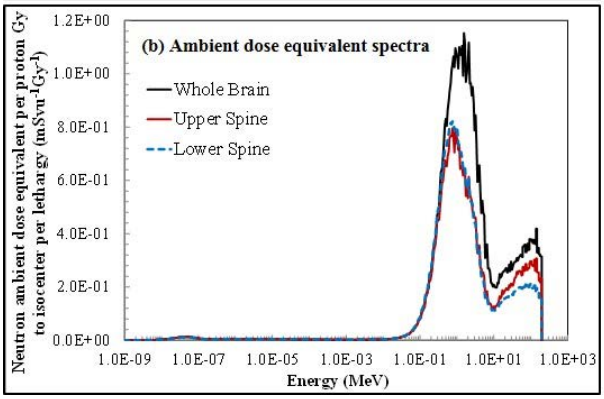

Conclusion: We measured neutron spectra and calculated neutron dose equivalents for a clinical treatment for a single gantry proton system, whose use and planned installations have recently increased. Data reported here are consistent with dose equivalents reported for CSI carried out with other proton therapy beamlines.

PO-0834

Calibrating absolute malignant induction probabilities into life-time attributable risk

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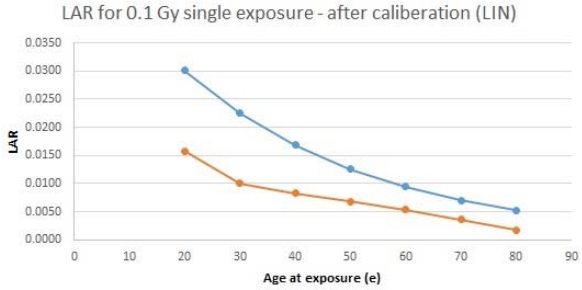
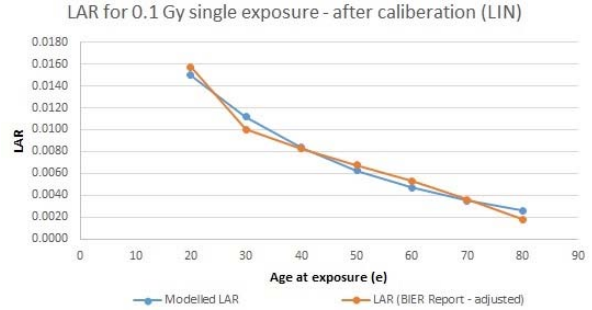
Purpose or Objective: More than half of cancer patients receive radiotherapy for radical or palliative purposes. Increasing survival rates in cancer patients make it important to study late side-effects, including secondary radiation-induced cancers. Although a number of predictive models exist, the absolute accuracy of these models in the radiotherapy dose range is limited partly due to scarcity of data and partly by extrapolation beyond historical data bounds. The aim of this work is to investigate conversion of malignant induction probabilities, which provide useful relative risk estimates, into absolute life time attributable risk estimates (LAR) and excess absolute risk (EAR) by calibrating and benchmarking our models using published outcome data.

Material and Methods: An in-house modelling tool, which calculates voxelwise risk estimates from patient-specific 3D dose distributions, was modified to generate linear-no-threshold (LNT) model-based risk estimates for the whole body and per organ using organ-equivalent dose. Second cancer risk was calculated for uniform whole-body exposure of 0.1 Gy for comparison with tabulated BIER VII data. Model parameters initially used were taken from existing published reports for the relevant models. The calculated LAR was then compared to the BIER VII results and the linear coefficient, λ, was adjusted to make the model prediction better match the BEIR VII result. A similar calibration of parameters was then performed for the linear quadratic (LQ) and linear model (LIN) malignant induction coefficients. EAR was calculated for a dose range to compare results with published data.

Results: After calibration, calculations of LAR for single uniform exposure of 0.1 Gy produced a value of 837 cases per 100,000 for an exposure at age of 40, in comparison to 824 according to BIER VII report. Averaging over ages at exposure of 20 to 80 produced a value within 5% of the BIER VII report. Calculations of EAR for a dose range relevant to RT of 1-6 Gy using the LIN model were always within the range of uncertainty due to differences in RBE neutron value in the independent published Hodgkin Lymphoma data (Schneider et al, 2008).





Conclusion: These results show that our models can produce absolute LAR estimates for secondary cancer which are consistent with the values reported in the BEIR VII report for uniform irradiation to 0.1Gy. The comparison of our results of EAR using LIN model to published data showed agreement with independent published data of HL.

PO-0835

A system for measuring and calculating neutron doses in paediatric proton patients

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Purpose or Objective: There is increased use of proton therapy in pediatric cancer patients. In treatment planning, neutrons produced in the treatment delivery system and the patient are usually ignored and not documented. The goal of this ongoing project is to develop and establish a system for measuring and simulating 3D neutron and gamma radiation fields of passively scattered and actively scanned proton beams using representative clinical proton fields impinging on tissue-equivalent phantom materials. Eventually this should lead to a standardized approach for calculating organ neutron doses in paediatric proton patients.

Material and Methods: The neutron dosimetry consists of neutron and gamma fluence measurements with an array of three organic scintillators positioned 70-80 cm lateral to blocks of tissue equivalent materials (soft tissue and compact

bone, CIRS) which are at isocenter and irradiated with therapeutic protons beams. The tissue equivalence of the irradiated materials for neutron doses (per incident proton) and energy spectra has previously been established with Geant4 simulations. Pulse shape discrimination is used to classify each detected pulse as either a neutron or a gamma ray, which allows selective analysis of the neutron and gamma ray spectra. Data are acquired using a digital measurement system based on a CAEN DT5720 waveform digitizer (12 bit, 250 MHz). The response of the scintillators is also simulated using a detection post-processor distributed with a modified version of MCNPX (PoliMi code). To validate the code, the total simulated neutron pulse height distributions scaled to the absolute fluence recorded during the measurements is compared with the measured distributions from the scintillators.

Results: There was good agreement (within 10%) of neutron dose and energy spectra for investigated tissue equivalent materials when compared to ICRP human tissues. So far measurements have been performed at three different proton treatment centers and measurements at two additional centers are planned, thus testing the system on a range of contemporary proton beam accelerators and beam delivery systems. Good agreement was found between the detector responses and Monte Carlo simulations. Using MCPNX, it was shown that the secondary neutron field can be separated into two distinct components; an isotropic, low-energy component and a forward-directed, high-energy component.

Conclusion: The neutron dosimetry system is applicable to any proton facility and will be valuable for prospective data collection of neutron doses and second cancer risk evaluation, thus establishing the dosimetric basis for a prospective clinical data base for paediatric proton patients.

PO-0836

Low dose out-of-field radiation: calculation, measurement and radiobiological impact on cells

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Purpose or Objective: The study presented here is three-part work whose primary aims were to determine a) the properties of the scattered radiation responsible for out-of-field doses b) the out-of-field radiation doses at varying distances from the primary beam, and c) the impact of these doses to biological response of in-vitro cells.

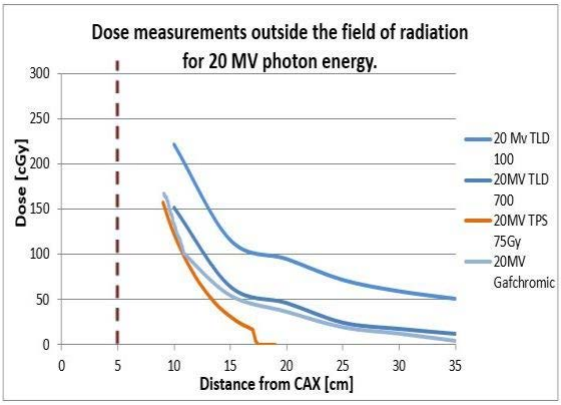
Material and Methods: We developed a purpose-designed water phantom to study out-of-field radiation. The phantom consists of seven dual-purpose inserts that can be used to measure doses and to assess radiobiological effects at the same measuring points. The photon (6 MV) energy spectra were calculated at 5 unique positions (at depths of 0.5 1.6, 4, 6, 8, and 10 cm) along the central beam axis (CAX) and at six different off-axis distances. To gain a better understanding of out-of-field doses, we measure the individual contribution of photons and neutrons to the total out-of-field dose for 6 MV and 20MV photons at open beam. Radiation doses were measured at 6 separate points in the phantom with TLD 100, TLD 600, TLD 700, and Gafchromic EBT films. Cells from the human breast cancer line MDA-MB-231 were inserted in a water phantom and irradiated at CAX and off-axis distance, at varying doses (1.5, 2.0, 2.5, 3.0 Gy). Survival fraction, number of DNA double strand-breaks (DNA DSBs), and cleaved PARP levels were determined by clonogenic assay and flow cytometry.

Results: Measured Monte Carlo simulations showed that mean radiation energy levels drop rapidly beyond the edge of the 6 MV photon beam field (Table 1). Simulations showed that the energy level actually increased slightly in some cases as the distance from the field edge increased. At a prescribed dose of 75 Gy to the isocentre, the measured photon dose level in the close-to-field area could reach up to 2.0-2.5Gy for 6MV and 1.5-2.0Gy for 20MV. Although the dose decreased rapidly as the distance from the CAX increased, even distant doses could reach several cGy when photons were used (Fig. 1). The neutron dose for 20 MV photons at a distance of 25 cm from the isocentre was 3.5 mSv/Gy. A slight non-significant decrease of 3-5% in cell SF was observed in cells irradiated outside the primary field.

Table 1. The mean photon energy at depths of 0.5, 1.6, 8 and 10 cm on the central axis (0 cm) and at 10, 15, 20, 25, 30 and 35 cm from the CAX at open (10x10 cm) beam.

	Mean energy [MeV]						
	Distance from beam central axis [cm]						
Depth [cm]	0	10	15	20	25	30	35
0.5	1.514	0.296	0.248	0.295	0.275	0.214	0.279
1.6	1.456	0.319	0.205	0.252	0.221	0.250	0.234
8.0	1.181	0.239	0.241	0.174	0.201	0.204	0.225
10.0	1.178	0.278	0.245	0.186	0.204	0.213	0.247

Figure 1. Dose measurements outside the field of radiation for 20 MV photon energy.



Conclusion: The dose levels measured in this study strongly suggest that out-of-field doses (especially for 20 MV) should be taken in consideration to obtain radiation protection of patients, as these dose levels could increase second cancer risk. Scattered irradiation appears to induce an in vitro biological response on out-of-field cells.

Poster: Physics track: Treatment plan optimisation: algorithms

PO-0837

Automatic treatment planning improves clinical quality of Head and Neck cancer treatments

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Purpose or Objective: Treatment plans for head and neck (H&N) cancer are highly complex due to multiple dose prescription levels and numerous organs at risk (OAR) close to the target. The plan quality is inter-planner dependent since it is dependent on the skills and experience of the dosimetrist. This study presents a blinded clinical comparison